

DOT/FAA/AM-04/16

Office of Aerospace Medicine
Washington, DC 20591

In-Flight Medical Incapacitation and Impairment of U.S. Airline Pilots: 1993 to 1998

Charles A. DeJohn ¹

Alex M. Wolbrink ²

Julie G. Larcher ¹

¹Civil Aerospace Medical Institute

Oklahoma City, OK 73125

²American Airlines

Dallas Fort Worth Airport, TX 75261

Civil Aerospace Medical Institute

Federal Aviation Administration

Oklahoma City, OK 73125

October 2004

Final Report

This document is available to the public
through the National Technical Information
Service, Springfield, Virginia 22161.



U.S. Department
of Transportation

**Federal Aviation
Administration**

NOTICE

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents thereof.

Technical Report Documentation Page

1. Report No. DOT/FAA/AM-04/16		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle In-Flight Medical Incapacitation and Impairment of U.S. Airline Pilots: 1993 to 1998				5. Report Date October 2004	
				6. Performing Organization Code	
7. Author(s) DeJohn CA ¹ , Wolbrink AM ² , Larcher JG ¹				8. Performing Organization Report No.	
9. Performing Organization Name and Address ¹ FAA Civil Aerospace Medical Institute P.O. Box 25082 Oklahoma City, OK 73125 ² American Airlines Dallas Fort Worth Airport, TX 7526				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Office of Aerospace Medicine Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplemental Notes					
16. Abstract <p>Although it is not known when the first accident due to pilot in-flight medical incapacitation occurred, a recent survey showed that almost one-third of all pilots who responded had experienced an incapacitation requiring another crewmember to take over their duties, with safety of flight significantly threatened in 3% of cases. The importance of in-flight medical incapacitation and impairment can be better understood when it is realized that each in-flight medical incapacitation or impairment could potentially lead to an aircraft accident. We studied in-flight medical incapacitations and impairments in U.S. airline pilots from 1993 through 1998. We defined in-flight medical incapacitation as a condition in which a flight crewmember was unable to perform any flight duties and impairment as a condition in which a crewmember could perform limited flight duties, even though performance may have been degraded. We found 39 incapacitations and 11 impairments aboard 47 aircraft during the six-year period. All pilots were males. The average age for incapacitations was 47.0 years (range 25 to 59 years). The average age for impairments was 43.3 years (range 27 to 57 years). The in-flight medical event rate was 0.058 per 100,000 flight hours. The probability that an in-flight medical event would result in an aircraft accident was 0.04. Incapacitations significantly increased with age, with more serious categories in the older age groups. The most frequent categories of incapacitation were loss of consciousness, cardiac, neurological, and gastrointestinal. Safety of flight was seriously impacted in seven of the 47 flights and resulted in two non-fatal accidents.</p>					
17. Key Words Incapacitation, Impairment, Aircraft Accidents, Diversion			18. Distribution Statement Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 30	
				22. Price	

ACKNOWLEDGMENTS

We gratefully acknowledge Connie Peterman of Advancia™ for her technical support as the programmer for the Civil Aerospace Medical Institute Incapacitation Database and the hours spent in preparing and executing the many queries necessary to extract the data used in preparing this paper.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
In-Flight Medical Event Studies.....	1
Career Termination Studies	1
Simulator Studies	2
Questionnaire Studies	2
Epidemiological Studies.....	3
Summary of Incapacitation Study Methodologies	3
METHODS	3
RESULTS	3
Frequency and Rate of In-Flight Medical Events	3
Probability of an Accident Due to an In-Flight Medical Event.....	4
Age and Gender Distribution of In-Flight Events	4
Categories of In-Flight Medical Incapacitations.....	5
Categories of In-Flight Medical Impairments	6
Fatal In-Flight Medical Events.....	6
Safety of Flight and In-Flight Medical Events	7
In-Flight Medical Events and Similar Medical Histories	7
Diversion Resulting From In-Flight Medical Events.....	8
Aeromedical Certification Actions Resulting From In-Flight Medical Events.....	8
DISCUSSION	9
Frequency and Rate of In-Flight Medical Events	9
Probability of an Accident Due to an In-Flight Medical Event.....	9
Age Distribution of In-Flight Medical Events	10
Categories of In-Flight Medical Events	10
Fatal In-Flight Medical Events.....	10
Safety of Flight and In-Flight Medical Events	11
In-Flight Medical Events and Similar Medical Histories	11
Diversion Resulting From In-Flight Medical Events.....	11
Aeromedical Certification Actions Resulting From In-Flight Medical Events.....	12
CONCLUSIONS	12
REFERENCES	13
APPENDIX	A-1
Appendix A	A-1

IN-FLIGHT MEDICAL INCAPACITATION AND IMPAIRMENT OF U.S. AIRLINE PILOTS: 1993 TO 1998

INTRODUCTION

The first fatal aircraft accident occurred in 1909, and by the end of 1910 there were 38 aviation fatalities. For some time, it was believed the first accidents attributed to pilot in-flight medical incapacitation occurred in 1911; however, after reviewing these cases, Parmet and Underwood-Ground (28) believed that they were the result of pilot error. Therefore, the date of the first aircraft accident attributed to pilot in-flight medical incapacitation is still unknown.

Over the years there have been many studies of airline pilot medical incapacitation (4, 6, 8, 19, 23, 24, 29, 30). Most studies can be classified as either direct studies of in-flight medical events, career termination studies, simulator studies, questionnaire studies, or epidemiological studies. In addition, Li (22) recently performed a comprehensive review of pilot-related factors in aircraft accidents.

In-Flight Medical Event Studies

In 1969, Buley (4) summarized three sets of airline pilot incapacitation data. First, he reported on the progress of a collaborative study initiated by the International Civil Aviation Organization (ICAO) and performed by the International Federation of Air Line Pilots Associations (IFALPA) and the International Air Transport Association (IATA). Buley examined in-flight deaths of airline pilots between 1961 and 1968. He found 17 reported cases of airline pilot deaths, all resulting from heart disease. Five of the 17 cases ended in aircraft accidents, four of which were fatal, resulting in 148 fatalities. Another five cases nearly resulted in accidents. Of the 17 events, seven occurred on the ramp, five while enroute, four during approach, and one during landing roll-out. Buley next reviewed 42 cases of non-fatal in-flight incapacitation in pilots of IATA-member airlines between 1960 and 1966. In 24 of the 42 cases, causal organic disease was diagnosed. The most common categories of incapacitation were epileptiform manifestations (6), coronary occlusions (4), and renal/ureteric colic (4).

In 1975, Raboutet and Raboutet (30) reviewed 17 incidents of sudden incapacitation in French professional civil pilots between 1948 and 1972. They found five cases of myocardial infarction, three cases of angina pectoris, two cases of ischemic heart disease, two cases of epileptic seizures, and one case each of diabetes, pulmonary

embolism, cerebral vascular accident, atrial fibrillation, and intestinal hemorrhage of unknown etiology. Fortunately, none of the cases resulted in aircraft accidents or the death of the pilot, and only two cases resulted in the complete incapacitation of the pilot due to epileptic seizures. Raboutet and Raboutet stated that for an incapacitation accident to occur, the incapacity must: (1) affect the pilot at the controls, (2) be sudden, (3) be total, and (4) take place during a critical phase of flight.

Chapman reviewed IATA data and found 208 in-flight medical incapacitations between 1965 and 1977, which included 13 cardiac cases, or one cardiac incapacitation per year. He calculated the probability of an accident due to cardiac incapacitation to be about 10^{-10} , assuming: (1) one accident per 400 incapacitations (i.e., one accident every 400 years), (2) 600 flying hours per pilot per year, and (3) subtle incapacitation during a critical phase of flight (7).

Martin-Saint-Laurent and associates (23) found ten cases of sudden in-flight incapacitation out of a population of 1,800 Air France pilots and flight engineers from 1968 to 1988. The most common causes of in-flight incapacitation were cardiac arrhythmias (2) and epileptic seizures (2). Two out of the ten flights diverted. The two pilots who suffered epileptic seizures and one pilot from the arrhythmia group who had an in-flight episode of atrial fibrillation (followed by a cerebral vascular accident with hemiparetic and epileptic seizure on the ground following the flight) were all permanently grounded. Five others were temporarily grounded. No action was taken against one pilot who experienced hypoxia and another who experienced CO₂ intoxication.

Career Termination Studies

Preston (29) followed 1,000 United Kingdom airline pilots and found that 73 were permanently grounded for medical causes between 1954 and 1965. Of the 73 pilots, the most common causes for loss of employment were psychiatric (36), cardiovascular (8), respiratory (6), and diabetes (4). Preston attributed the low incidence of cardiovascular groundings to possible Anglo-Saxon racial differences between this group of pilots and other pilots, and the high incidence of psychiatric groundings to poor pilot selection procedures.

Lane (21) examined IATA loss of license insurance data and estimated the overall in-flight incidence of in-flight incapacitation to be 0.06 per 1,000 pilots per year.

Kulak, Wick, and Billings (20) performed a similar study of career termination due to loss of licensure insurance in members of the U.S. Airline Pilots Association from 1955 through 1966. They found 891 cases of career termination: 229 due to accidents and 662 the result of disease. The rate of death and disability due to accidents was 2.07 per 1000 pilots per year, while the rate for disease was 8.05 per 1000 pilots per year. Although the overall rate for cardiovascular disease was only 2.91 per 1000 pilots per year, the age specific rate ranged from zero for pilots under 30 years of age to 27.33 for pilots between 55 and 58 years of age. Flying accidents accounted for the majority of career terminations for all age groups. Using the incapacitation incidence rates for termination due to disease by age and the age distribution of active ALPA pilots, the authors estimated the probability of serious in-flight incapacitation by age. Their estimates ranged from 1 per 58,000 pilots for the 30-to 34 -year age group to 1 per 3,500 pilots for the 55-to 59- year age group.

Simulator Studies

Harper, Kidera and Cullen performed two simulator studies, one dealing with obvious and maximal loss of function (14), and the other with subtle or partial loss of function (13). Although operationally interesting, discoveries were made. For example, the mean time to detect subtle incapacitation was 1.5 minutes, and 25% of the simulator sessions ended in "aircraft accidents" (13). The studies, however, were not designed to address medical causes of in-flight incapacitation.

Chapman (7) analyzed more than 1,300 simulator exercises in which the subtle incapacitation of the flying pilot was programmed to occur at a critical phase of flight. Two protocols were used. The first involved 500 exercises where major aircraft system failures were simulated as part of the drill. In 485 of the 500 cases, it was determined there would not have been any danger to an actual aircraft. In 15 cases, it was believed that safety of flight would have been at risk. In eight cases, it was considered that aircraft accidents would have resulted. The second protocol involved 800 exercises without simultaneous aircraft system failures. In this series, only ten out of the 800 were felt to have represented a risk to safety of flight, and in two cases, the observers felt that an aircraft accident would have resulted. Again, these studies did not address medical causes of in-flight incapacitation.

There are inherent problems when simulator results are used to predict in-flight outcomes. Crews that "crashed" in the Harper, Kidera, and Cullen (13) study, for example, stated, "We wouldn't let it happen in a real

airplane." Also, in addition to the obvious difficulty of attempting to predict possible in-flight outcomes from simulated data in the Chapman study, there was the added drawback of foreknowledge by the subjects, since they knew there would be an incapacitation at some time during each drill.

Questionnaire Studies

Buley (4) reviewed the results of a questionnaire administered to pilots of IFALPA-member associations in 1967, in which 27% of approximately 5000 respondents reported about 2,000 incidents of significant in-flight incapacitation. Safety of flight was affected in 4% of cases. Almost one-half of reported incapacitations occurred in the enroute phase of flight. Unfortunately, the IFALPA questionnaire was administered to actively flying airline pilots; therefore, pilots with more serious medical conditions, who may have suffered more severe types of incapacitation, had been previously eliminated and were not part of the study. This skewed the data by eliminating the potential for reporting more serious medical conditions while including the less serious conditions reported by actively flying pilots. In addition, most of the conditions addressed in the questionnaire were temporary in nature and would usually result in pilot impairment (i.e., nausea, vomiting, indigestion, etc.) rather than total incapacitation and would not likely be addressed by medical certification.

In 1971, Lane (21) updated the 1967 IFALPA questionnaire data, analyzed by Buley (4), with IATA data for 1962 through 1968 that was provided to ICAO. Lane added 51 additional, non-accident cases to Buley's original 17 cases, for a total of 68 cases. He then calculated the probability of an incapacitating event resulting in an accident would be 5/68, or 0.074.

In 1991, James and Green (19) replicated Lane's 1967 IFALPA survey with similar results. Of 1,251 respondents, 29% reported at least one incident of in-flight incapacitation severe enough to require another crewmember to assume their duties. The most common causes of incapacitation were gastrointestinal (58.4%), earache due to a blocked ear (13.9%), and faintness or general weakness (8.5%). The most common phases of flight where incapacitations occurred were enroute (42.1%), followed by climb (18.4%), descent (17.3%), and on the ramp (11.4%). Safety of flight was felt to be potentially affected in 45% of cases and definitely affected in 3% of cases. Of those reporting that safety of flight had been affected, 43% stated the incapacitation event placed the remaining aircrew under maximum workload. As with the 1967 Buley study, the questionnaire was administered to actively flying airline pilots, again eliminating the potential for reporting more

serious medical conditions. In addition, the study did not provide incapacitation rates which would allow for comparison with similar studies.

Epidemiological Studies

Castello-Branco and associates (6) found 13 deaths and eight medical incapacitations in a longitudinal evaluation of deaths and disease in 408 active Portuguese airline pilots between 1945 and 1983. The most common causes of death were accidents, myocardial infarcts, and cancer. By relating the number of deaths and incapacitations with the number of pilots at risk, they calculated incidence rates by age group. Death and incapacitation rates ranged from zero per 100 pilots at risk for the 20 to 24 year age group, to 3.64 per 100 pilots at risk for the 55 to 59 year age group. Although this is an excellent longitudinal study of airline pilots for an extended period and provides valuable insight into causes of death and disease, it does not directly reflect causes of in-flight incapacitation.

Summary of Incapacitation Study Methodologies

Most previous studies we reviewed did not use data from actual in-flight medical events. Instead, indirect measures, such as career termination due to permanent medical grounding or loss of licensure insurance data and general epidemiological data, were used to approximate the frequency of in-flight medical events. These studies provided information on the frequency and categories of in-flight medical events; however, they did not include incapacitation rates, making meaningful comparison between studies difficult. Although in-flight medical incapacitation rates can be inferred, these data are not directly based on in-flight medical events.

The objective of this study was to provide incapacitation rates that could be easily compared with similar studies of in-flight medical incapacitation.

METHODS

Details of aircrew in-flight medical events aboard U.S. airlines between 1993 and 1998 were collected by the Federal Aviation Administration (FAA), Civil Aerospace Medical Institute's (CAMI's), Aerospace Medical Research Team (AMRT) and stored in a Microsoft Access 2000® Database (Version 9.0). The official method of case notification was through the use of a Medical Case Alert Form (Appendix A, Table A-1); however, many cases were discovered through the FAA Administrator's *Daily Bulletin*, telephone calls, news media, periodic searches of the National Transportation Safety Board (NTSB) and FAA accident databases, and direct interaction between the CAMI and the NTSB.

Event data included incident, operational, pilot, and final disposition information. Incident information included a brief narrative and/or full report of the event when available, including injuries and/or fatalities. Operational information included the date, time, location, type of operation, accident or incident classification, phase of flight, airline, flight number, aircraft number, type of aircraft, origin, destination, and diversion details. Pilot information included the pilot's name, social security number, age, gender, class of medical certificate, pilot certificate number, FAA medical history, aircrew position, occupation, and employer. NTSB numbers were recorded, and a unique CAMI Incapacitation Database number was also assigned to each case. The authors could not independently verify the validity of much of the information collected from sources outside of CAMI, including aircrew statements, airline records, and hospital records, etc. In most cases, this information had to be accepted without confirmation.

Cases were reviewed by the authors and classified as either an "impairment" or "incapacitation." Individuals were classified as impaired when they could still perform limited in-flight duties, such as read checklists or perform radio communications, even though their performances may have been degraded. Examples of impairments include food poisoning, the use of monovision contact lenses, fatigue, and kidney stones. Individuals were considered incapacitated when they could no longer perform any in-flight duties. Examples of incapacitation include heart attacks and epileptic seizures.

Cases were also classified as "possible," "probable," or "certain" depending on the degree of confidence in the supporting evidence. For airline events, the other aircrew members were witnesses to the occurrence, and reports were required by the airline. In addition, in cases serious enough to require further evaluation and treatment, the hospital record provided additional confirmation.

Each case was also assigned to one of several broad medical categories. Incapacitation categories included loss of consciousness, cardiac, neurological, gastrointestinal, urological, vascular, medication, hypoxia, decompression sickness, and injury. Impairment categories included respiratory, cardiac, gastrointestinal, infectious disease, vision, and reaction to medication.

RESULTS

Frequency and Rate of In-Flight Medical Events

We found 39 incapacitations and 11 impairments of U.S. airline pilots on 47 flights during the period 1993 to 1998 (More than one pilot was affected on three flights. See Table A-2, Case Summaries, in Appendix A.). During

this period, U.S. airlines flew a total of 85,732,000 revenue passengers hours (26); therefore, the rate of in-flight incapacitations and impairments was 0.04549 per 100,000 hours (95% CI 0.04545, 0.04553) and 0.01283 per 100,000 hours (95% CI 0.01281, 0.01285), respectively. A summary of the in-flight medical events is contained in Appendix A, Table A-2.

Probability of an Accident Due to an In-Flight Medical Event

There were two non-fatal aircraft accidents due to the in-flight medical impairment of the pilots. One was caused by the pilot's visual impairment due to the use of monovision contact lenses during an approach. The other was caused by flight crew fatigue. Combining the 39 incapacitations and 11 impairments gives 50 in-flight medical events on 47 flights; therefore, the probability that an in-flight medical event would be associated with an accident was 2 out of 50 events, or 0.04.

There were 54,295,899 flights and 217 accidents involving U.S. Part 121 scheduled and non-scheduled airlines between 1993 and 1998 (25, 27). The probability of an aircraft accident for a pilot experiencing an in-flight medical event is summarized in Table 1.

Table 1. The Probability of an Accident Given an In-Flight Medical Event.

		Accident		
		Yes	No	Total
In-Flight Event	Yes	2	48	50
	No	215	54,295,634	54,295,849
	Total	217	54,295,682	54,295,899

The "law of rare events" states that the total number of events of interest will assume (approximately) the Poisson distribution if: (a) the event may occur in any of a large number of trials, but (b) the probability of occurrence in any given trial is small. Examples of events that follow a Poisson distribution are doctor visits, absenteeism in the workplace, mortgage pre-payments, loan defaults, bank failures, insurance claims, and aircraft accidents (5). Assuming that accidents involving pilot in-flight medical events can be described using a Poisson distribution, there is a statistically significant difference between the proportion of accidents given an in-flight medical event, compared with the proportion of accidents in the absence of such an event ($z = 3.08$, $p < 0.001$).

Age and Gender Distribution of In-Flight Medical Events

All pilots who had an in-flight event were males. The average age for incapacitations was 47.0 years (range 25 to 59 years) while the average age for impairments was 43.3 years (range 27 to 57 years). Figure 1 shows the age distribution for the percentage of U.S. airline pilots having in-flight incapacitations and impairments between 1993 and 1998 based on the average age distribution for professional pilots (from a recent FAA study; Appendix A, Fig. A-1) (3).

Examination of Figure 1 suggests an increase in in-flight medical incapacitations with increasing U.S. airline pilot age.

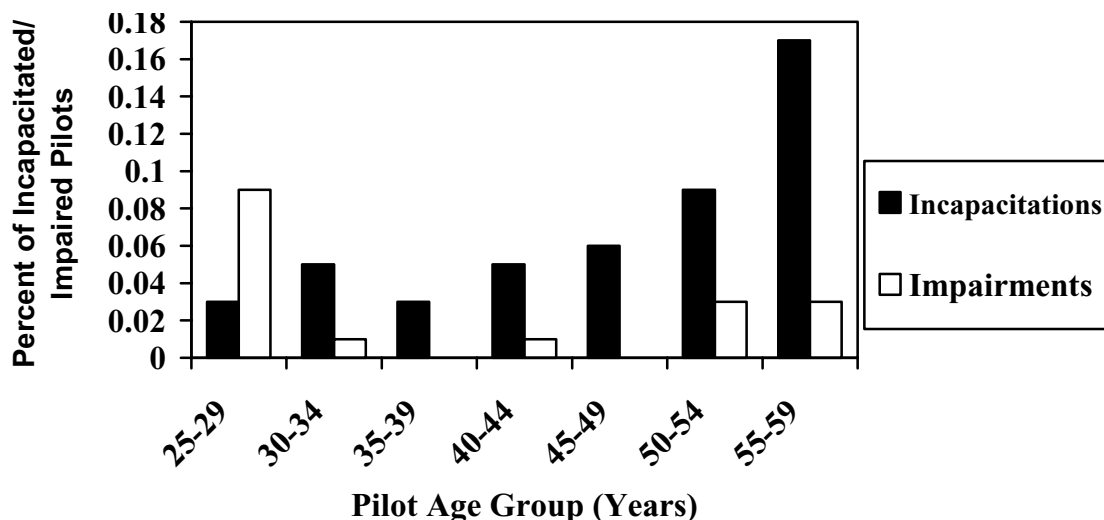


Figure 1. Percent of U.S. airline pilot in-flight incapacitations and impairments as a function of age (1993 to 1998).

Figure 2 shows the percent of pilot in-flight medical incapacitations by age group. A linear regression of the data shown in Figure 2 indicates that the percentage of in-flight incapacitations increased with pilot age group ($R^2 = 0.69$, $p < 0.01$).

Categories of In-Flight Medical Incapacitations

All 39 in-flight medical incapacitations were classified as “certain.” The most frequent categories were loss of consciousness (LOC) (9), gastrointestinal (GI) (6), neurological (6), cardiac (5), and urological (3). Of the nine loss of consciousness cases, four were caused by vasovagal syncope, one was the result of neurogenic syncope, one was due to pain secondary to a duodenal bulb ulcer, one was the result of decompression sickness, and two were due to unknown causes. The six gastrointestinal

cases included two cases of cholelithiasis, two cases of intestinal gas expansion with altitude, and two cases of possible food poisoning. Four of the six neurological cases were grand-mal seizures, one was an alcohol withdrawal seizure, and one was a petit mal seizure. Three of the five cardiac cases were fatal myocardial infarctions, and one was a fatal dysrhythmia, while one cardiac case involved a non-fatal coronary spasm. All three urological cases involved renal lithiasis.

Figure 4 shows the most frequent categories of in-flight medical incapacitation by age. Examination of the figure suggests an increase in incapacitations with pilot age. Also, the data in Figure 4 suggest that more serious categories, such as loss of consciousness secondary to ulcers, cardiac events like myocardial infarctions, and neurological seizures occurred more frequently in older

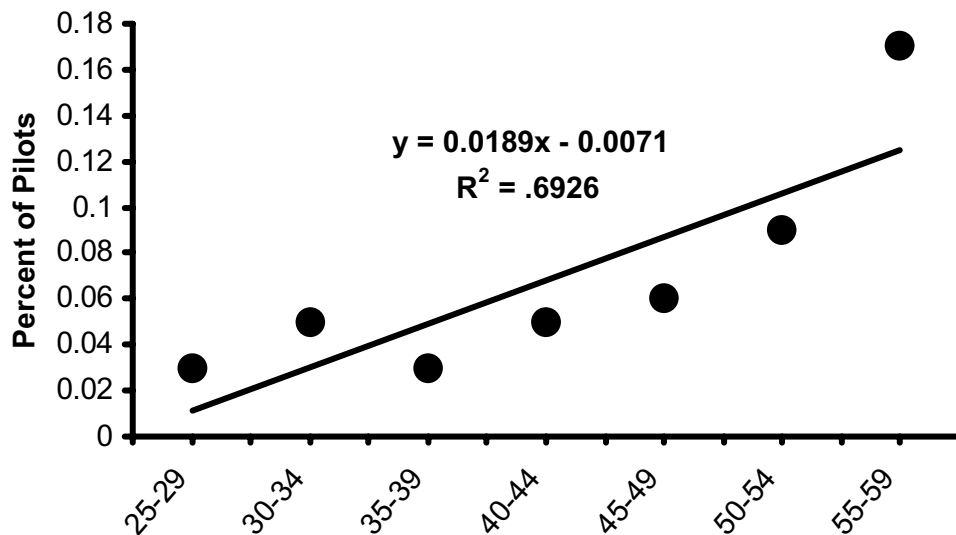


Figure 2. Age distribution of in-flight medical incapacitations of U.S. airline pilots from 1993 to 1998.

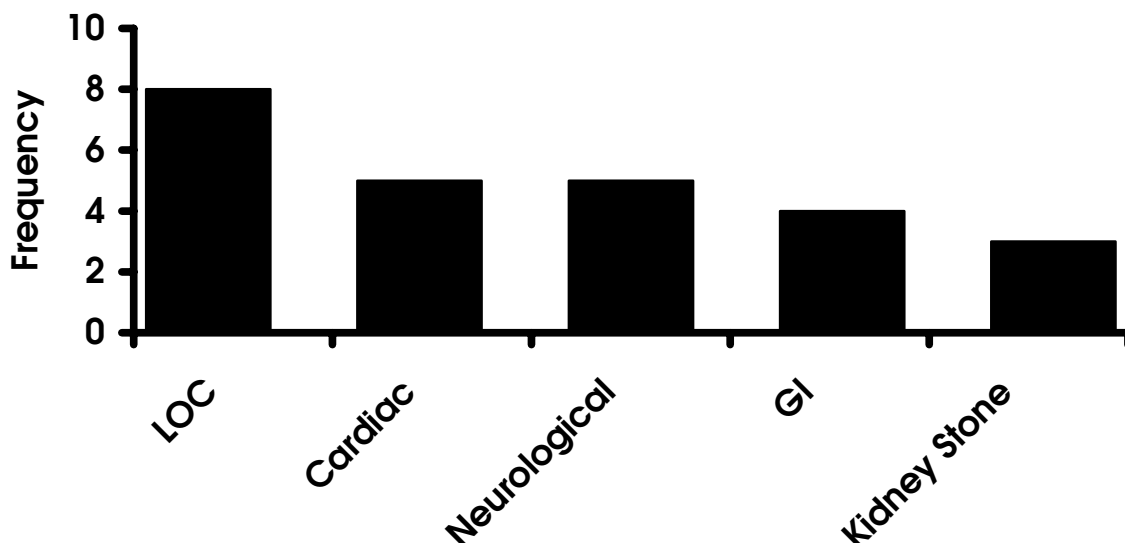


Figure 3. Frequent categories of in-flight medical incapacitation.

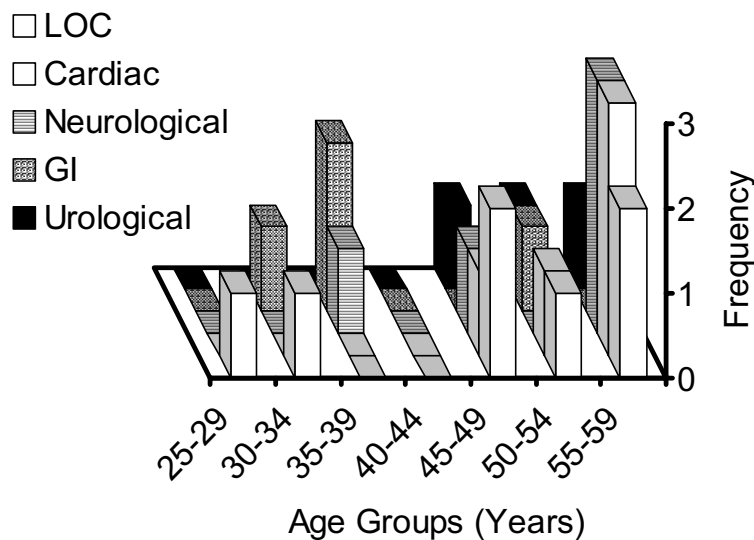


Figure 4. Most frequent categories of in-flight medical incapacitation by age.

pilots. At the same time, the less serious medical categories, such as gastrointestinal events due to gas expansion and food poisoning and loss of consciousness due to vasovagal syncope, occurred more frequently in younger pilots.

Less frequent causes of in-flight medical incapacitation included hypoxia (2), diabetes (1), decompression sickness (1), vascular (1), reaction to medication (1) and traumatic injury (1). The two hypoxia cases occurred on the same flight when the flight engineer inadvertently opened the outflow valve at altitude, accidentally depressurizing the aircraft. The diabetes case involved a second officer who had had two hypoglycemic episodes within a three-month period, one at the gate resulting in his removal from the aircraft prior to flight and another in-flight. The decompression case occurred when a DC-8 cargo captain ordered his crew to continue to climb to 33,000 feet after it was determined that the aircraft could not be pressurized. Interestingly, the captain ordered the aircrew to use oxygen, believing that it would provide protection against decompression sickness at that altitude. The vascular case involved an Airbus captain with a history of chronic, controlled atrial fibrillation who decided to discontinue his digoxin and propranolol on his own and developed a temporoparietal cerebral infarct during landing. One pilot suffered heart palpitations that were attributed to an herbal medication he was taking for weight control; another suffered an injury when hydraulic fluid came into contact with his eye during an aircraft pre-flight inspection.

Categories of In-Flight Medical Impairments

All of the 11 in-flight medical impairments were classified as “certain.” Categories of in-flight medical impairment included respiratory (4), fatigue (2), vision

(2), cardiac (1), gastrointestinal (1), and infectious disease (1). Three of the four respiratory cases occurred on the same taxiing DC-8 aircraft when carbon dioxide poisoning, caused by fumes from dry ice carried in the cargo compartment, impaired the captain, first officer and jumpseater. The fourth respiratory case was due to barosinusitis. The two fatigue cases occurred on a DC-8 flight, resulting in an accident with three serious injuries. The captain had been awake 40 of the previous 66 hours and the first officer for 47 of the previous 66 hours prior to the accident. Of the two vision cases, one occurred when a B-737 captain looked directly into a laser that appeared to be tracking the aircraft from the ground, resulting in a temporary loss of night vision. The other occurred when an MD-88 struck the approach lights during an approach to a landing because of the captain’s use of monovision contact lenses, resulting in three minor injuries on evacuation of the aircraft. The cardiac case involved a 57-year-old L-1011 captain who had been experiencing retro-sternal chest pain since the previous day, which became more continuous in flight and began radiating to his left jaw and arm. Although the clinical impression of the attending physician was unstable angina, his electrocardiogram was normal on physical examination. One Embraer-120 captain was diagnosed with viral gastroenteritis and secondary dehydration, and an MD-88 first officer was found to have a viral infection that led to a vasovagal response.

Fatal In-Flight Events

Four pilots died as a result of their in-flight incapacitating event; however, no passenger deaths resulted from these incapacitations. No pilot deaths resulted from in-flight medical impairments. The mean age of the four

pilot fatalities was 53 (range 48 to 56 years). All four deceased pilots were pronounced dead because of cardiac events after being transported to the hospital. Three of the four deaths resulted from myocardial infarctions (MIs), while one was the result of a cardiac dysrhythmia. Two of the three pilots who suffered MIs and the pilot who died as a result of a fatal dysrhythmia had cardiac medical histories that were documented in the pilot's FAA medical record. As a result, pathology codes, history codes, or both were assigned by the FAA prior to their in-flight medical events. Two of the three flights where the pilots suffered an MI and the one flight where the pilot suffered an arrhythmia diverted to alternate airports because of the in-flight medical events; however, the one flight that did not divert when the first officer suffered an MI was inbound to their final destination at the time. Cardiopulmonary resuscitation was attempted in all cases. Safety of flight was seriously affected only once temporarily when the first officer's foot became lodged against the rudder pedal when he stiffened, requiring the captain to apply opposite rudder pressure until the foot could be dislodged.

Safety of Flight and In-Flight Medical Events

Safety of flight is negatively affected during any in-flight medical event; however, we considered safety of flight to be a factor during an event only when there was imminent danger of an aircraft accident resulting from the medical event. We found that on seven of the 47 flights it was seriously affected. The mean age of the seven pilots involved in flights where safety of flight was seriously affected was 48.4 years (range 42-56, SD = 4.5), and the mean age of the 41 pilots who were not involved in flights where safety of flight was seriously affected was 45.7 years (range 25-59, SD = 10.7). There was no significant difference in the mean age between the two groups. As previously discussed, two of the seven flights ended in aircraft accidents. The seven cases are summarized below.

- A 45-year-old B-737 first officer experiencing an alcohol withdrawal seizure suddenly screamed, extended his arms up rigidly, pushed full right rudder, and slumped over the yoke during an approach. The aircraft descended to 1,000 feet above ground level in an uncoordinated turn to 25 degrees angle of bank before flight attendants could pull the first officer off the controls, allowing the captain to recover the airplane. "Mayday" calls were made, and the captain executed a missed approach before making a successful landing.
- When a 48-year-old DC-9 first officer's foot became lodged against a rudder pedal after he

stiffened during a heart attack, the captain had to apply opposite rudder to control the aircraft until the foot could be dislodged.

- A 44-year-old flight engineer and a 42-year-old captain lost consciousness when the flight engineer accidentally turned off a flow pack with the cargo heat outflow valve open, depressurizing their B-727 at 33,000 feet. The captain and flight engineer regained consciousness only after the first officer donned his oxygen mask and made an emergency descent.
- A 49-year-old captain stiffened so violently during an epileptic seizure after landing that he suffered a fractured shoulder and a lumbar compression fracture. At the same time, he applied such force to the rudder pedals that he caused the aircraft to turn sharply and stop suddenly. The first officer had to remove the captain from the controls to taxi the aircraft to the gate.
- During an approach flown at higher than normal airspeed, a 56-year-old A-300 captain suffering a cerebral infarction did not ask for the landing gear to be extended and simply nodded agreement when the first officer questioned him about it. After touchdown, the captain used reverse thrust for longer than required and applied full take-off power on the taxiway. After the first officer reduced power, the captain again applied take-off power, and the first officer shut down the engines and called for assistance.
- When a 48-year-old MD-88 captain wearing monovision contact lenses attempted to make a visual approach over water under reduced lighting conditions in rain and fog, he perceived the aircraft to be higher than it actually was. This resulted in a steeper than normal final approach, causing the aircraft to strike the approach lights. Although no one was hurt on impact, three passengers received minor injuries during the evacuation following the accident.
- A cargo DC-8 crashed on approach because the aircrew's judgment, decision-making, and flying abilities were impaired by fatigue. The 50-year-old captain had been awake for 40 of the previous 66 hours, and the 54-year-old first officer had been awake for 47 of the previous 66 hours prior to the accident. The captain entered an approach turn stall and failed to recover, resulting in the accident, which caused serious injuries to himself, the first officer, and second officer.

In-Flight Medical Events and Similar Medical Histories

There are times when the airman's FAA medical record contains coding that is similar to the category assigned to an in-flight event. While we found no pilots whose in-flight medical impairments were categorized similarly to

the codes assigned in their FAA medical history, nine of 39 incapacitations were categorized similarly to the codes assigned in the pilot's FAA medical record, as shown in Table A-3.

Diversions Resulting From In-Flight Medical Events

A flight diversion occurs whenever the aircraft lands at a destination other than the originally intended airport. Nineteen of the 39 flights involving incapacitated pilots and three of the 11 flights with impaired pilots diverted because of the in-flight medical event. The odds of a flight diverting is, therefore, 0.48 (95% CI 0.33, 0.64) in the case of an in-flight medical incapacitation and 0.27 (95% CI 0.01, 0.54) in the event of an impairment. In three of the 19 diversions (16%) for incapacitated pilots, the aircrew-member did not survive, while in all three diversions for impaired pilots the affected crewmember did survive.

Of the 19 diversions for incapacitated pilots, three were classified as cardiac cases, three as gastrointestinal, three as epileptic seizures, two as hypoxia, and eight due to other causes. Two of the three cardiac cases were fatal heart attacks, 1 in a 48-year-old pilot and the other in a 56-year-old, and one was a fatal arrhythmia in a 55-year-old pilot. One of the gastrointestinal cases was due to food poisoning, 1 the result of intestinal gas expansion with an increase in altitude, and the third was suspected to be peritonitis. The two hypoxia cases occurred on the same flight when the flight engineer accidentally depressurized the aircraft at 33,000, and both the captain and flight engineer temporarily lost consciousness. The first officer eventually donned his oxygen mask and made an emergency descent. Eight cases classified as "other" included decompression sickness, unknown loss of consciousness, cholelithiasis, renal lithiasis, muscle cramps, chest pain of unknown origin, vertigo secondary to labyrinthitis, and vasovagal syncope.

The three diversions for impaired pilots included 1 case of cardiac chest pain in a 57-year-old pilot due to unstable

angina, 1 case of viral infection leading to a vasovagal syn-copal response in a 51-year-old, and 1 case of barosinusitis during climb in a 43-year-old.

Aeromedical Certification Actions Resulting From In-Flight Medical Events

The 39 in-flight medical incapacitations led to 16 medical certificate denials (Table A-2, cases 2, 5, 7, 9, 12, 13, 18, 21, 37, 38, 39, 89, 96, 100, 175, and 178). In addition, a special-issuance code was assigned to 1 pilot (Table A-2, case 2), 16 history codes were assigned to ten pilots (Table A-2, cases 2, 5, 11, 12, 27, 32, 33, 73, 82, and 175), 37 pathology codes were assigned to 22 pilots (Table A-2, cases 2, 5, 7, 9, 10, 11, 12, 13, 14, 18, 21, 29, 31, 32, 37, 38, 39, 73, 95, 96, 175, and 178), and four EKG codes were assigned to 1 pilot (Table A-2, case 12). Also, 11 pilot medical certificates were reaffirmed (Table A-2, cases 14, 20, 33, 34, 35, 39, 81, 82, 87, 95, and 98), five pilots were eventually re-certified (Table A-2, cases 2, 5, 9, 18, and 73), and in two cases, no codes needed to be assigned (Table A-2, cases 16 and 17).

The 11 in-flight medical impairments led to three denials (Table A-2, cases 19, 218, and 219). In addition, six pathology codes were assigned to three pilots (Table A-2, cases 19, 218, and 219), three medical certificates were reaffirmed (Table A-2, cases 30, 74, and 86), and in five cases, no codes were assigned (Table A-2, cases 83, 84, 85, 97, and 148).

Figure 5 shows the trend in the number of aeromedical certification actions per in-flight medical event (incapacitations and impairments) for all types of actions, including the assignment of special issuance codes, electrocardiogram codes, history codes, pathology codes, as well as certificate denials, re-certification, and reaffirmation. As shown in the figure, there was a significant decrease in the number of aeromedical certification actions per event between 1993 and 1998 ($p < 0.05$).

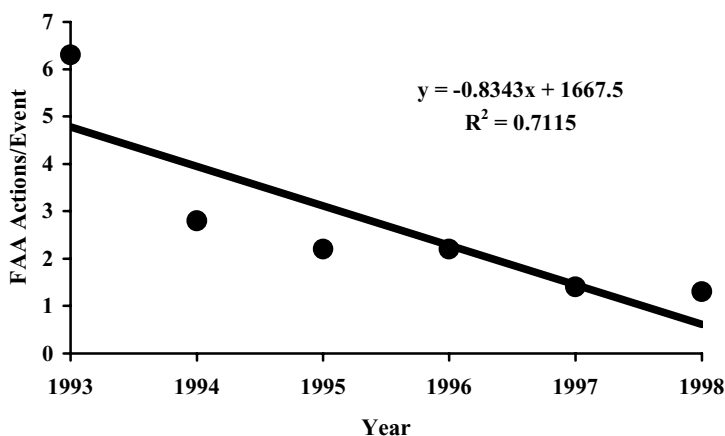


Figure 5. The trend of FAA actions per in-flight medical events.

DISCUSSION

Frequency and Rate of In-Flight Events

We found 39 in-flight medical incapacitations for a rate of 0.045 per 100,000 hours and 11 impairments for a rate of 0.013 per 100,000 hours on 47 U.S. airline flights between 1993 and 1998. It is interesting that there were approximately four times as many incapacitations as impairments, since impairments were generally less serious events and could be expected to occur at least as frequently as incapacitations. This is probably a reporting phenomenon. Incapacitated pilots were generally more seriously ill than impaired pilots. Consequently, incapacitations resulted in more declared emergencies, flight diversions, ambulance requests, and hospitalizations than impairments. Therefore, an incapacitation would probably have been better documented than an impairment. Since many of the impairment cases were less well documented, any record would have depended on pilot self-reporting, something that would probably be avoided by most pilots.

Ironically, only two accidents resulted from pilot in-flight medical impairments, while no incapacitations resulted in accidents. This may have been because of the insidious nature of the two impairment accidents. When a dramatic incapacitating event, such as a heart attack or epileptic seizure occurs, it is often obvious and can be dealt with by the unaffected crewmember. In the two impairments that ended in aircraft accidents, the pilots were probably not aware there was a problem. In one case, the pilot normally flew with monovision contact lenses. In the other, the pilots were probably aware they were fatigued but were not cognizant of how seriously it was impacting their performance at the time.

Martin-Saint-Laurent et al. (23) studied sudden in-flight incapacitation in Air France pilots and flight engineers from 1968 to 1988 and reported an incapacitation incidence of 0.044 per 100,000 flight hours. While this is very close to the rate found for incapacitations in this study, the Martin-Saint-Laurent et al. study included categories that would have been classified as impairments in this study; therefore, a more appropriate comparison would be to include incapacitations and impairments together. Combining incapacitations and impairments gives a total of 48 in-flight medical events and a rate of 0.059 per 100,000 flight hours, which is only slightly higher than the rate in the Martin-Saint-Laurent et al. study.

A review of all U.S. Air Force (USAF) accidents coded for incapacitation, preexisting disease, or other acute illnesses between 1978 and 1987 yielded an incapacitation rate of 0.019 per 100,000 flight hours (24). This rate is

less than half the rate in the Martin-Saint-Laurent (23) study and this study; however, the USAF study involved military pilots who may have been younger and in better physical condition, and it was restricted to events that resulted in aircraft accidents. We found that incapacitations rarely resulted in accidents; in fact, there were no accidents among the Martin-Saint-Laurent et al. cases and two accidents in this study, neither of which was fatal.

Two additional studies dealing with U.S. airline pilots were based on loss of licensure data, rather than in-flight events, and reported incapacitation rates based on the number of pilots incapacitated per year instead of flight time (20, 21); therefore, their results could not be compared with the results of this study in a meaningful way.

The two major airline pilot incapacitation studies that dealt with in-flight medical events provide only qualitative results (4, 19), which do not allow for meaningful comparison with other quantitative studies.

Probability of an Accident Due to an In-Flight Medical Event

Froom reported that less than 1% of all aircraft accidents are due to pilot in-flight incapacitation (11). Lane calculated a probability of 5/68 or 0.074 (21). However, Lane included categories that were classified as impairments in our study. Combining incapacitations and impairments in this study, we calculated the probability of an accident to be 2/50 or 0.04, about half of the probability found in the Lane study. The difference in proportions may be due to differences in the types of aircraft operations in the two studies. While we have included only U.S. airline pilot in-flight medical events, only two of the five flights in the Lane study were airline flights, and one of those was a positioning flight. Also, two of the five accidents in the Lane study involved cargo aircraft, and one was a Department of Defense charter flight.

The proportion of military pilot in-flight medical incapacitations leading to accidents was much higher, probably due to the difference in the operational environment. Rayman reported that the probability of an accident was 20/146, or 0.14, in one study of Air Force pilot incapacitations from 1970 to 1980 (32), and 28/59, or 0.47, in another Air Force study from 1966 to 1971 (31).

Although we found a statistically significant difference between the chance of an accident (given there was an in-flight medical event), compared with flights where there was no in-flight medical event, this difference must be interpreted in terms of its operational significance. The in-flight events in the two accidents are not representative of most other in-flight events. In neither case was the flight crew acutely affected by a medical condition

in the same sense as a pilot who suffers chest pain from a heart attack or abdominal pain from a kidney stone, for example. These events might have ultimately led to an accident because they did not represent dramatic events that could have been detected and dealt with by the unaffected pilot. Some authors have made clear distinctions between obvious and subtle incapacitation (7, 14). Raboutet and Raboutet even asserted that an incapacitation needed to be complete for an accident to result (30). However, it is easy to imagine scenarios that involve: (1) incapacitation of the non-flying pilot, which increases the workload on the flying pilot to an unsafe level, (2) the subtle, insidious incapacitation of a crewmember that is not apparent until a critical phase of flight, (3) the partial incapacitation of a crewmember that degrades performance to an unsafe level, and (4) the incapacitation of a crewmember during a non-critical phase of flight that continues into a critical phase, resulting in an unacceptable increase in workload for the flying pilot. Any of these situations could result in an aircraft accident without meeting the Raboutets' criteria. In addition, Crowley (8) also found the conditions described by Raboutet and Raboutet overly restrictive. Our findings suggest that a subtle, unperceived impairment might be more dangerous than an obvious, complete incapacitation. Although safety of flight was severely affected in seven of the 47 flights studied, accidents resulted in only two of those flights. In the other five flights, where the incapacitating event was not subtle, the unaffected pilot was able to recognize the emergency and prevent an accident, even in those situations where the event occurred on short final.

Age Distribution of In-Flight Medical Events

Some studies examining the Age 60 Rule for airline pilots have focused on pilot performance and aircraft accident data (3, 16, 17, 18). Hyland et al. studied all accidents involving pilots with Class I medical certificates and found a decrease in accident rate with age (16, 17, 18). Broach et al. found a "U"-shaped curve with a decrease in accidents with increasing age, followed by a slight increase in older age groups for professional pilots holding Class I or II medical and ATP or Commercial pilot certificates (3).

Other researchers have suggested that replacement of older, experienced pilots by younger, inexperienced pilots could adversely affect flight safety, and it may be preferable to grant waivers to experienced pilots with an increased incidence of disease-related, in-flight sudden incapacitation than to replace them with younger, inexperienced pilots (2, 11). Froom reported that inexperienced pilots have a two to three time increased incidence of pilot error-

related accidents and cautioned that the estimated risk of in-flight medical incapacitation needed to be balanced by a consideration of pilot experience (11).

We found a significant increase in the percentage of incapacitations with age among the most frequent categories of in-flight medical incapacitation for U.S. airline pilots; however, we did not find a significant difference between the mean age of pilots where safety of flight was seriously impacted and those pilots where safety of flight was not seriously at issue.

Categories of In-Flight Medical Events

Although many studies have dealt with pilot medical incapacitation, few have analyzed in-flight medical events (6, 7, 13, 14, 19, 21, 29). Studies of in-flight medical events had different results or categorized cases differently, making comparison between studies difficult; however, we found no significant differences between four in-flight studies (4, 24, 31, 32) when they were compared by categorizing cases with the same classification scheme used in this study and compared using a Krushal-Wallis ANOVA.

Fatal In-Flight Medical Events

Only three in-flight medical incapacitation studies reported fatalities (24, 30, 31); however, it was not always clear when fatalities occurred or how many fatalities occurred in several other studies. Rayman reported 24 fatalities in a six-year study of sudden in-flight incapacitation in USAF pilots, or four fatalities per year (31). In addition, in a ten-year study of in-flight incapacitation in USAF pilots, McCormick and Lyons (24) found one pilot was fatally injured in the crash of his single-seat aircraft after suffering a myocardial infarction in-flight, for a rate of 0.1 fatalities per year, while Raboutet and Raboutet (30), in a 25-year investigation of professional French pilots, found that one pilot suffered a massive pulmonary embolism in-flight and died about one month post-crash, yielding a rate of 0.04 fatalities per year.

We found four deaths in our six-year study, which equates to 0.67 fatalities per year. The wide range in fatality rates per year from 0.04 to four in other studies can be partially explained by the fact that pilot fatalities resulting from in-flight medical incapacitation are very rare, random events; therefore, exposure time should be considered in evaluating them. Fatality rates based on flight-time exposure were not provided in earlier studies; therefore, comparisons were not possible. Accounting for flight-time exposure, we calculated a fatality rate of 0.00467 per 100,000 flight hours (95% CI 0.00465, 0.00468).

Safety of Flight and In-Flight Medical Events

Chapman (7) analyzed over 1,300 simulator exercises using two protocols. In the first protocol, the authors determined that safety of flight was at risk in 15 out of 500 (3%) of the cases, and it was felt that an accident would have resulted in eight (1.6%) cases. In the second protocol, ten out of 800 (1.25%) were felt to have represented a risk to safety of flight; in two (0.25%), the authors believed aircraft accidents would have resulted.

A survey by the International Federation of Airline Pilots Associations conducted by Bennett (1) showed that the pilots surveyed considered that safety was only significantly threatened in 3% of the incidents because there was time available to warn the other pilot of the problem.

Buley (4) reviewed IFALPA in-flight incapacitation questionnaire data and reported that 40% of responding aircrew members felt that safety of flight was not affected, 56% believed it was potentially affected, and 4% were convinced that safety of flight was actually affected.

Our data showed that safety of flight was severely impacted in 15% (7 out of 47) of the flights we studied. This figure is higher than those reported by Chapman, Bennett, or Buley. Differences in the percentage of flights where safety of flight was impacted might be due to differences in methods among studies. In our study, we reviewed actual in-flight events and judged whether the circumstances would have severely impacted safety of flight. In the studies conducted by Chapman, the researchers were required to determine if what was done in a flight simulator would have affected safety of flight in the aircraft under similar circumstances. The Buley study was the only one that collected safety of flight data directly from aircrew members; however, Buley's study would have relied on the ability of pilots to recall details of events that may have occurred many years earlier. Stone and Shiffman (34) recently reported that retrospective assessments may be prone to recall bias and distortion. In addition, Hunter (15) recently reported that exposure to hazardous aviation events may be associated with risk misperception by pilots. These factors suggest why pilots in the Buley study might have perceived the risk to safety of flight for a past event as being less than it actually was.

In-Flight Medical Events and Similar Medical Histories

There are times when the airman's FAA medical record contains coding that is similar to the category assigned to an in-flight event. We found no pilots whose in-flight medical impairments were categorized similarly to the codes assigned in their FAA medical record. However,

nine of 39 incapacitations were categorized similarly to the codes assigned in the pilot's FAA medical record as shown in Table A-3. It should be noted that the similarities between the assigned incapacitation categories and the corresponding FAA medical codes do not necessarily imply a cause-and-effect relationship and do not, in any way, suggest the airman should not have been medically certified because of the documented pre-existing condition. For example, an airman with hypertension controlled with medication may be assigned a pathology code of 485 and issued a valid medical certificate. If the airman then suffers a stroke in-flight, it might be argued that there could have been a relationship between the airman's hypertension and the stroke, since hypertension is a risk factor for stroke. However, the stroke could also have resulted from an undiagnosed cerebral aneurism.

In addition, an FAA medical code does not necessarily imply the airman should have been disqualified. Airmen often have codes assigned (pathology codes, history codes, or EKG codes) to indicate the presence of medical conditions that are not disqualifying.

Diversions Resulting From In-Flight Medical Events

Diversions for medical purposes represent a significant problem for commercial air carriers (9). Delay to original destination, passenger inconvenience, increased risk to safety, and cost factor into the complexity of aircraft diversions (12). The exact cost of a medical diversion typically ranges between approximately \$3,000- \$100,000, depending upon whether fuel needs to be dumped before landing and whether or not passenger overnight accommodations are arranged (33). Landing weight is also a consideration, and valuable fuel may have to be jettisoned to attain a suitable landing weight for a premature touchdown. While it is more difficult to put a dollar amount on safety of flight, this is perhaps the most important consideration in any diversion situation. If the unaffected pilot is forced to proceed via an unplanned route to an unexpected destination and perform an unfamiliar instrument approach, this could reduce the margin of safety still further in an already hazardous situation.

Nineteen of the 39 flights involving incapacitated pilots and three of the 11 flights with impaired pilots diverted. The diversion rate for all in-flight medical events was 22 out of 47, or 46.8% of flights. This is over twice the 20% diversion rate reported by Martin-Saint-Laurent et al. (23) in a study of in-flight incapacitation in commercial aviation in Air France pilots and flight engineers from 1968 to 1988. Since the methodologies of the two studies are very similar, the difference in percentages of diverted flights are probably due to other factors. One reason

might be differences in the corporate culture between U.S. airlines in the 1990s and Air France in the 1960s that might have influenced the flight crews' decision whether to divert. Another reason could be differences in the type of operation between the U.S. domestic airlines and Air France. For example, if many of the Air France flights were international flights, diversions for medical events may not have been practical because continuing to the destination would often be as appropriate.

Aeromedical Certification Actions Resulting From In-Flight Medical Events

The pathology, history, and EKG codes assigned as a result of FAA Aeromedical Certification Division (AMCD) action become part of the airman's FAA medical record and have been incorporated into the new computerized Document Imaging and Workflow System (DIWS). It must be noted that more than one type of action was taken in some cases. For example, a pilot may have been assigned a pathology code, been denied as a result of an in-flight medical event, and then eventually re-certified with a special issuance medical certificate.

Although there was a significant decrease in the number of certification actions per in-flight medical event with time, it did not appear to reflect any change in FAA aeromedical certification policy, nor did it appear to be a function of the frequency of in-flight medical events. In fact, the frequency of events increased with time, and the effect of frequency was accounted for in Figure 5. One possible explanation for the trend was the chance distribution of events. An examination of the events showed those which occurred between 1993 through 1995 generally required more certification actions, while the events from 1996 to 1998 generally required fewer certification actions. Between January 1, 1993, and December 31, 1995, there were two cases of fatigue resulting in an aircraft accident with serious injuries, an alcohol withdrawal seizure, three cardiac events, three neurological events, a vasovagal syncopal episode, two episodes of loss-of-consciousness, and two miscellaneous events. The average number of FAA certification actions per event for this group was 3.6. In contrast, between January 1, 1996, through December 31, 1998, there were two neurological cases, three cardiac cases, four cases of vasovagal syncope, five gastrointestinal cases, three cases of carbon dioxide poisoning, two cases of hypoxia, three cases of renal lithiasis, two cases of unknown losses of consciousness, and two miscellaneous cases. In addition, there was one case each in the following categories: endocrine, vascular, vision, trauma, laser illumination blindness, medication use, and respiratory. The mean number of FAA aeromedical certification actions per event for the post-1996

group was 1.7, which is about half that of the pre-1996 group. Therefore, the decreasing trend in the number of certification actions with time appears to have been due to random causes and not any purposeful change in FAA aeromedical certification policy.

In-flight medical incapacitation and impairment cases are regularly reviewed at CAMI medical staff meetings attended by physicians from the Aerospace Medical Certification and the Aerospace Medical Research Divisions. Details of the in-flight event, as well as the pilot's medical history, are evaluated in deciding what action to take and which codes to assign. This process is very important because it may affect future aeromedical certification decision-making, should the airman develop future medical problems or experience another in-flight event.

It is important to note the FAA actions taken in the 39 in-flight medical incapacitation cases and 11 impairment cases we studied represent action after the fact. In many instances, the FAA Aerospace Medical Certification Division denies medical certification applications for airline pilots, possibly preventing many serious in-flight events. One FAA study (10) reported an overall denial rate for medical reasons of 4.3 per 1,000 active aviators for calendar years 1987 and 1988. The highest age-specific denial rate was for the 55-to-59 age group, and the most significant causes for denial for all age groups were coronary artery disease (8.5%), disqualifying medications (6.2%), psychoneurotic disorders (6.1%), myocardial infarction (5%), and disturbance of consciousness (4.4%).

CONCLUSIONS

In-flight medical events in U.S. airline pilots were very rare; resulting aircrew deaths were even more rare, and resulting aircraft accidents were extremely rare. Fortunately, in the six years and nearly 86 million flight hours covered by this study, there were no passenger fatalities caused by pilot in-flight medical events. The two aircraft accidents resulted in serious injuries to three aircrew members and minor injuries to three passengers.

One study, focusing on professional pilot performance and aircraft accident data, found a curvilinear relationship between pilot age and performance (3). Still, other researchers have argued that replacement of older, experienced pilots by younger, inexperienced pilots could adversely affect flight safety. We found a significant increase in the percentage of incapacitations with age. However, there was no difference between the mean age of pilots involved in flights where safety of flight was seriously affected and the mean age of pilots not involved in such flights.

Although there was a significant difference between the probability of an aircraft accident, given an in-flight medical event, this result must be interpreted in its operational context. Both accidents involved the subtle impairment of the pilot in ways that are not classically thought of as medical incapacitation, and it may be that subtle impairment of a pilot is more dangerous than obvious medical incapacitation.

The most important factor that appears to be responsible for the exceptionally good U.S. airline safety record associated with in-flight medical incapacitations is the presence of a second pilot. In five out of the seven cases where safety of flight was considered to be severely impacted, the aircraft was taken over by the unaffected pilot who made a successful landing. In the two cases where the affected pilot remained at the controls after subtle impairment, both resulted in an aircraft accident.

Aeromedical studies on incapacitation have been few in number, retrospective, and less detailed than most other scientific studies. There is a lack of high-quality data, which has led to a lack of adequate research and inadequate information and recommendations. To be most valuable, future research needs to be based on actual in-flight medical events and should be normalized to a useful denominator, such as flight time, to allow for meaningful comparison between studies. Since the most frequent categories of incapacitation were loss of consciousness, cardiac, neurological, and gastrointestinal (occurring mostly in older pilots), future research should be directed toward these areas.

REFERENCES

1. Bennett G. Medical-cause accidents in commercial aviation. *Euro Soc Card* 1992; 13 (Supplement H):13-15.
2. Bennett G. Pilot incapacitation and aircraft accidents. *Euro Heart J* 1988; 9 (Supplement G):21-4.
3. Broach D, Joseph, KM, Schroeder DJ. Pilot age and accident rates report 3: An analysis of professional air transport pilot accident rates by age. Oklahoma City, OK: Federal Aviation Administration, Civil Aerospace Medical Institute. 2003: OAM Research Task AAM-00-A-HRR-520.
4. Buley LE. Incidence, causes and results of airline pilot incapacitation while on duty. *Aero Med* 1969; 40 (1):64-70.
5. Cameron A, Trivedi P (1988). Regression analysis of count data. New York, NY: Cambridge University Press.
6. Castelo-Branco A, Cabral-Sa A, Borges JC. Comparative study of physical and mental incapacities among Portuguese airline pilots under and over age 60. *Aviat Space Environ Med* 1985; 56:752-7.
7. Chapman P. The consequences of in-flight incapacitation in civil aviation. *Aviat Space Environ Med* 1984; 55:497-500.
8. Crowley J, Campbell J, Johnson P, Powell JA. Coronary artery disease and in-flight incapacitation. *U.S. Army Medical Department Journal* 2000; (July-September):17-22.
9. Davies G, Degotardi P. In-flight medical emergencies. *Aviat Space Environ Med* 1982; 53(7):694-700.
10. Downey L, Dark S. Medically disqualified airline pilots in calendar years 1987 and 1988. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine. 1990; DOT/FAA/AM-90/5.¹
11. Froom P, Benbassat J, Gross M, et al. Air accident, pilot experience, and disease-related in-flight sudden incapacitation. *Aviat Space Environ Med* 1988; 59:278-81.
12. Goodwin T. In-flight medical emergencies: An overview. *BMJ* 2000; 321:1338-41.
13. Harper C, Kidera G, Cullen J. Study of simulated airline pilot incapacitation: Phase II. Subtle or partial loss of function. *Aero Med* 1971; 42 (9):946-8.
14. Harper C, Kidera G, Cullen J. Study of simulated airline pilot incapacitation; Phase 1 – obvious and maximal loss of function. *Aero Med* 1970; 41 (10): 1139-42.
15. Hunter DR. Risk perception and risk tolerance in aircraft pilots. Washington, DC: Office of Aerospace Medicine. 2002; DOT/FAA/AM-02/17.¹
16. Hyland D. Experimental evaluation of aging and pilot performance. 7th International Symposium on Aviation Psychology. 1993; Columbus, OH.
17. Hyland D, Kay E, Deimler J, et al. Age 60 rule research, Part II: Airline pilot age and performance – A review of the scientific literature. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine. 1994; DOT/FAA/AM-94/21.¹

¹This publication and all Office of Aerospace Medicine technical reports are available in full-text from the Civil Aerospace Medical Institute's publications Web site: <http://www.cami.jccbi.gov/aam-400A/index.html>

18. Hyland D, Kay E, Deimler J. Age 60 rule research, Part IV: Experimental evaluation of pilot performance. Washington, DC: Federal Aviation Administration, Office of Aviation Medicine. 1994; DOT/FAA/AM-94/23.¹
19. James M, Green R. Airline pilot incapacitation survey. *Aviat Space Environ Med* 1991; 62:1068-72.
20. Kulak LL, Wick RL, Jr., Billings CE. Epidemiological study of in-flight airline pilot incapacitation. *Aero Med* 1971; 42 (6):670-2.
21. Lane JC. Risk of in-flight incapacitation of airline pilots. *Aero Med* 1971; 42 (12):1319-21.
22. Li G. Pilot-related factors in aircraft crashes: A review of epidemiologic studies. *Aviat Space Environ Med* 1994; 65:944-52.
23. Martin-Saint-Laurent A, Lavernhe J, Casano G, et al. Clinical aspects of in-flight incapacitations in commercial aviation. *Aviat Space Environ Med* 1990; 61:256-60.
24. McCormick TJ, Lyons TJ. Medical causes of in-flight incapacitation: USAF experience 1978-1987. *Aviat Space Environ Med* 1991; 62:884-7.
25. NTSB. [http://www.nts.gov/NTSB/query.asp#query_start 10/24/02](http://www.nts.gov/NTSB/query.asp#query_start%2010/24/02).
26. NTSB. Accidents and accident rates by NTSB classification, 1982 through 2001, for U.S. air carriers operating under 14 CFR 121, <http://www.nts.gov/aviation/Table2.htm> on 10/30/02.
27. NTSB. Accidents, fatalities, and rates, 1982 through 2001, for U.S. air carriers operating under 14 CFR 121, scheduled and nonscheduled service (airlines), <http://www.nts.gov/aviation/Table5.htm> on 2/24/02.
28. Parmet A, Underwood-Ground K. Reported in-flight incapacitation: The early birds of 1911. *Aviat Space Environ Med* 1987; 58:276-8.
29. Preston FS. Twelve year survey of airline pilots. *Aero Med* 1968:312-4.
30. Raboutet J, Raboutet P. Sudden incapacitation encountered in flight by professional pilots in French civil aviation, 1948-1972. *Aviat Space Environ Med* 1975; 46 (1):80-1.
31. Rayman R. Sudden incapacitation in flight: 1 Jan 1966 - 30 Nov 1971. *Aero Med* 1973; 44 (8):953-5.
32. Rayman R, McNaughton GB. Sudden incapacitation: USAF experience, 1970-80. *Aviat Space Environ Med* 1983; 54 (2):161-4.
33. Rodriguez A, Golaszewski R. (2004). Some preliminary evidence on the costs to airlines and passengers of schedule disruptions: working paper. Jenkintown, PA, GRA Inc.
34. Stone A, Shiffman S. Capturing momentary, self-report data: A proposal for reporting guidelines. *Ann Behav Med* 2002; 24 (3):236-43.

APPENDIX A

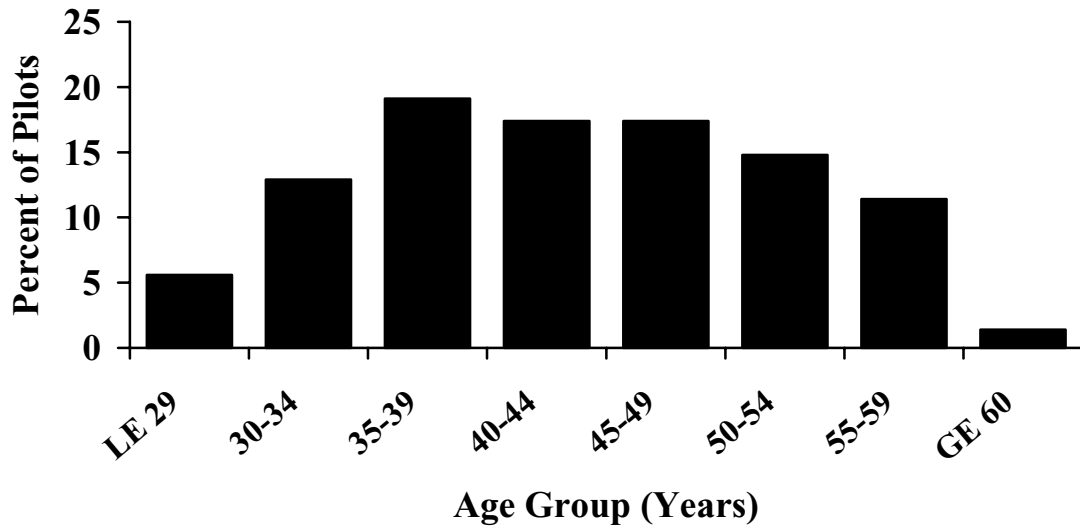


Figure A-1. Average age distribution of U.S. professional pilots from 1993 to 1998 (3). Inclusion criteria included: air transport pilots or commercial pilots, class-I or -II medical certificate, occupation professional pilot, employer CFR Part 121 or 135 operator, 200 recent flight hours and at least 1500 total flight hours.

Table A-1. Medical Case Alert Form.

MEDICAL CASE ALERT

(Including incapacitations, special medical circumstances, etc.)

1. AIRCRAFT ACCIDENT/INCIDENT	1A. DATE	1B. TIME	1C. LOCATION	1D. NUMBER/TYPE
1E. NUMBER OF PERSONS ON BOARD		1F. PILOT FATALITY <input type="checkbox"/> YES <input type="checkbox"/> NO		1G. COPILOT FATALITY <input type="checkbox"/> YES <input type="checkbox"/> NO
2A. OCCUPANT STATUS	X Pilot <input type="checkbox"/> Cabin Crew <input type="checkbox"/> <input type="checkbox"/> CoPilot <input type="checkbox"/> Passenger		2B. FULL NAME	2C. SEX <input type="checkbox"/> Male <input type="checkbox"/> Female
3. MEDICAL CLASS <input type="checkbox"/> I <input type="checkbox"/> II <input type="checkbox"/> III	3A. SOCIAL SECURITY NUMBER (Airmen Only)			
3B. ANY KNOWN MEDICAL CONDITIONS (ex: SODA, SI, Undisclosed medication or condition, Path Codes)				
4. INJURY STATUS				
5. ESTIMATED ROLE OF INCAPACITATION		<input type="checkbox"/> NONE <input type="checkbox"/> POSSIBLE <input type="checkbox"/> CERTAIN		
6. ESTIMATED ROLE OF IMPAIRMENT		<input type="checkbox"/> NONE <input type="checkbox"/> POSSIBLE <input type="checkbox"/> CERTAIN		
7. POSSIBLE FACTORS INVOLVED IN THE MISHAP		<div style="display: flex; justify-content: space-between;"> <div style="width: 48%;"> 7a. <input type="checkbox"/> Medical condition 7b. <input type="checkbox"/> Medication 7c. <input type="checkbox"/> Alcohol 7d. <input type="checkbox"/> Marijuana/Illicit drug 7e. <input type="checkbox"/> Carbon Monoxide 7f. <input type="checkbox"/> Pesticide </div> <div style="width: 48%;"> 7g. <input type="checkbox"/> Hypoxia 7h. <input type="checkbox"/> Spatial disorientation 7i. <input type="checkbox"/> Fatigue 7j. <input type="checkbox"/> Emotional Stress 7k. <input type="checkbox"/> Other (specify) </div> </div>		
8. TOXICOLOGICAL DATA	PERFORMED BY: Address 1: Address 2: City: State: Zip Code: Phone:		FINDINGS:	
9. AUTOPSY DATA	PERFORMED BY: Address 1: Address 2: City: State: Zip Code: Phone:		COMMENTS: Pending	
10. FAA/NTSB IIC FEEDBACK	PROVIDED BY: Address 1: Address 2: City: State: Zip Code: Phone:			
11. NARRATIVE COMMENTS: (Elaborate on any of the above, or other significant factors. Use a separate sheet if additional space is needed.)				
<div style="display: flex; justify-content: space-between; padding-top: 20px;"> Medical person completing form: (Name) (Phone) DATE: </div>				

Table A-2. Case Summaries.

Case Summaries							
Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)							
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category	CAMI Narrative
2	1994	45	Yes	No	Incapacitation	ALCOHOL WITHDRAWAL SEIZURE	The first officer suddenly screamed, extended his arms up rigidly, pushed full right rudder and slumped over the yoke. Aircraft descended to 1,000 feet before flight attendants pulled the F/O off the controls. "Mayday" calls were made and the captain made a full missed approach before making a successful normal landing. Oxygen was administered for about 7 minutes. F/O had another grand mal seizure at the hospital.
3	1994	52	No	Yes	Incapacitation	CARDIAC	Aircraft was on approach with the first officer flying when his left arm slid off the throttles and the airman lay back in the seat. CPR was performed. It appeared to be a heart attack.
4	1994	55	No	Yes	Incapacitation	CARDIAC	The captain became limp at the controls. CPR was performed. The second officer moved into the captain's seat, the F/O declared an emergency and the flight diverted where an uneventful, overweight, landing was made. The captain was transported to hospital where he was pronounced dead.
5	1995	59	No	No	Incapacitation	VASOVAGAL	The captain lost consciousness and slumped across the center pedestal. Oxygen was administered and the captain regained consciousness in 30 to 40 seconds. However, he passed out again, and recovered again. First officer landed the aircraft; captain taxied to the gate.
6	1995	48	Yes	Yes	Incapacitation	CARDIAC	The first officer complained of heartburn, profuse sweating, tingling in both of his arms and nausea. His appearance was described as ashen gray. The captain assumed control. Symptoms passed and he resumed flying. First officer complained that the heartburn pains were returning so the captain assumed control and diverted. First officer eventually lost consciousness, began twitching and stiffened, and loudly exhaled. CPR was performed. The first officer's left leg had become lodged against the left rudder when he stiffened, requiring the captain to apply right rudder to control the aircraft until the F/O's leg was dislodged.

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)							
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category	CAMI Narrative
7	1995	57	No	No	Incapacitation	NEUROLOGICAL	During descent from cruise, the captain failed to respond to a heading from Air Traffic Control and did not respond to the first officer. What was described as a grand mal seizure followed. The F/O landed the aircraft and the captain was taken to local area hospital. (Hospital suspected a brain tumor of the left temporal lobe).
9	1995	56	No	No	Incapacitation	LOSS OF CONSCIOUSNESS GASTROINTESTINAL	The captain became nauseated, stomach became bloated and uncomfortable then he lost consciousness. The flight was diverted. Upon landing the captain was taken to hospital.
10	1995	41	No	No	Incapacitation	MISCELLANEOUS	The first officer experienced severe back pain soon after take-off. The captain declared an emergency, and the flight returned to its place of origin.
11	1996	37	No	No	Incapacitation	GASTROINTESTINAL	The first officer became medically incapacitated inflight, and the flight diverted. The F/O was admitted to hospital for treatment of possible peritonitis. He remained in hospital for two days and was sent home by train. The first officer had had an appendectomy two months previous to the incident.
12	1996	56	No	No	Incapacitation	VASOVAGAL GASTROINTESTINAL	The captain experienced severe abdominal pains and became medically incapacitated in flight. He was taken to hospital, where workups including CTscan, gastro consultation, and treadmill tests concluded event as probable gastroenteritis with vasovagal response. He had a near-syncopal episode during treadmill. Neuro and gastrointestinal work-ups were within normal limits.
13	1996	43	No	No	Incapacitation	ENDOCRINE	The second officer became hypoglycemic. He was on oral anti-hypoglycemic agents and had a similar episode six weeks prior at the gate. This resulted in the airman being removed from the aircraft prior to the flight. Medical certificate was surrendered by the airman.
14	1996	47	No	No	Incapacitation	VASOVAGAL GASTROINTESTINAL	Take-off was aborted due to the first officer's incapacitation. F/O had slumped over in the cockpit but "recovered" as they were taxiing back to the gate. He appeared pale and was sweating profusely. The F/O was taken to hospital and held overnight. The airman reported eating a bad sandwich the day before.

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)						
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category
16	1996	44	Yes	No	Incapacitation	HYPOXIA
The aircraft experienced decompression at 33,000 feet. The first officer made an emergency descent. It appears the flight engineer may have turned off the right flow pack with the cargo heat outflow valve open. Cabin altitude increased toward 33,000 ft and the first officer donned his mask. The captain, flight engineer, and flight attendant lost consciousness but regained during descent. Oxygen masks deployed for all passengers. The captain took over the aircraft and landed.						
17	1996	42	Yes	No	Incapacitation	HYPOXIA
The aircraft experienced decompression at 33,000 feet. The first officer made an emergency descent. It appears the flight engineer may have turned off the right flow pack with the cargo heat outflow valve open. Cabin altitude increased toward 33,000 ft and the first officer donned his mask. The captain, flight engineer, and flight attendant lost consciousness but regained during descent. Oxygen masks deployed for all passengers. The captain took over the aircraft and landed.						
18	1996	31	No	No	Incapacitation	VASOVAGAL
While the aircraft was climbing through 28,000 feet the first officer went limp and slumped to left side of seat. Attempts to revive him were unsuccessful. After approximately 20 to 30 seconds he started to stir a little, then abruptly started flailing about. The flailing lasted about 10 seconds, knocking off the captain's glasses and turning on the deice switches on the overhead panel. The F/O then came to. Over a period of about five minutes the airman regained full consciousness, but was drenched in sweat, and "as white as my shirt." Airman became fully coherent with complete situational awareness. The flight then proceeded normally to the alternate airport. Initial evaluation was negative and electrocardiogram was normal.						
19	1996	57	No	No	Impairment	CARDIAC
In-flight, the captain began experiencing chest pain. The airman reported experiencing intermittent retrosternal chest pain since the previous day, which was becoming more continuous with radiation to his left jaw and left arm. The flight diverted, the captain taxied the aircraft to the gate. The clinical impression was chest pain with possible unstable angina.						

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)						
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category
20	1996	41	No	No	Incapacitation	MISCELLANEOUS
The captain experienced chest pains during flight. A nurse who was on board stated that he appeared pale and anxious; the flight diverted. Upon landing the airman was taken to the hospital for treatment. The captain was admitted and kept overnight for observation. Electrocardiogram was performed; he was without chest pain upon entry to the emergency room, stress test performed and enzymes tested. All studies were normal.						
21	1996	56	Yes	No	Incapacitation	VASCULAR
A scheduled domestic passenger flight was stopped on the taxiway after landing when the captain became incapacitated. The first officer stated that the captain was flying the aircraft, and during the approach the captain did not ask for the landing gear to be extended. The approach to the runway was flown at a higher than normal speed and after touchdown the captain used reverse thrust for a longer than normal time. After exiting the runway onto the taxiway the captain applied takeoff engine power. The first officer closed the engine power levers, the captain again tried to apply takeoff engine power. The F/O realized the captain was incoherent and closed the engine power levers and shut down the engines. He then called for assistance from the flight attendants and asked the air traffic controller to send out rescue personnel.						
27	1997	37	No	No	Incapacitation	GASTROINTESTINAL
While enroute, the first officer experienced severe stomach pain. The captain decided to divert. Paramedics took the first officer to hospital. Diagnosis: severe intestinal gas blockage.						
29	1997	54	No	No	Incapacitation	TRAUMATIC INJURY
While the first officer was performing the pre-flight check, a drop of hydraulic fluid (Skydrol) entered into his eye. The airman was then taken to the local hospital where the eye was washed out.						
30	1997	34	No	No	Impairment	LASER ILLUMINATION BLINDNESS
The captain was on the controls when he noticed a green light illuminating the aircraft. He reported that his exposure to the light caused a minimal, yet persistent loss of night vision.						
31	1997	58	No	No	Incapacitation	UROLOGICAL
First officer declared an emergency due to the incapacitation of the captain. An onboard doctor determined it was a stomach related problem. The captain was vomiting, had pain in stomach, and was very weak. The first officer landed the aircraft. The captain was taken to hospital, and kidney stones were passed.						

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)						
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category
32	1997	51	No	No	Incapacitation	GALL BLADDER
33	1997	53	No	No	Incapacitation	GASTROINTESTINAL
34	1997	54	No	No	Incapacitation	GALL BLADDER
35	1997	30	No	No	Incapacitation	MEDICATION
37	1998	38	No	No	Incapacitation	NEUROLOGICAL (SEIZURE)
38	1998	48	No	No	Incapacitation	UNKNOWN LOSS OF CONSCIOUSNESS
39	1998	50	No	No	Incapacitation	UNKNOWN LOSS OF CONSCIOUSNESS

CAMI Narrative

Enroute, the first officer developed severe abdominal pains. The captain radioed that the F/O had "gas pain with significant discomfort" and requested paramedics meet the aircraft, an emergency was declared. The F/O was taken to hospital. Diagnosis was gallbladder attack; subsequently surgery was performed.

The captain became ill with flu-like symptoms, nausea, vomiting and diarrhea during a transatlantic flight. An onboard physician said the captain was suffering from acute gastroenteritis, secondary to food poisoning.

The flight declared an emergency and made an unscheduled landing because the flight engineer had a suspected heart attack. The airman was transported to hospital in stable condition. Working diagnoses was cholelithiasis.

An emergency was declared after the first officer experienced chest pains. The pilot was taken to the local hospital. Preliminary reports indicated the chest pains were not cardiac related.

The first officer was on a break, and asleep when a flight attendant noticed he was bleeding from his mouth and tongue. The airman was awakened and appeared disoriented. It was assumed the F/O had a seizure while sleeping. The airman was taken to a hospital and had a seizure while having an ECG.

The captain experienced severe abdominal pain during flight. He collapsed in his seat and was unresponsive. The captain reported eating at a Cuban restaurant. Complaints were diarrhea, vomiting, sweating, panting, and abdominal pain. The hospital found him to be dehydrated and administered approx 3½ liters of fluid.

The first officer was found unresponsive and an onboard physician was called to attend him. He appeared to have had a seizure and appeared to be unconscious for 30 minutes. He walked through the airport and refused medical attention from the paramedics who had been sent to meet him at the gate; he also refused to be checked at a hospital.

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)							
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category	CAMI Narrative
72	1998	56	No	Yes	Incapacitation	CARDIAC	The first officer told his captain that he was not feeling well shortly before suffering an apparent heart attack. He was observed slumped over in his seat. The flight diverted. CPR was given. Paramedics were waiting at the gate six minutes after the F/O collapsed, but they were unable to revive him.
73	1998	50	No	No	Incapacitation	UROLOGICAL	During flight, the captain suffered severe back pain. The flight diverted. The pain went away after landing but returned on the way to the hospital. An IVP at the hospital revealed dilation at the left urethral-vesicular junction, most likely due to a kidney stone.
74	1998	51	No	No	Impairment	VASOVAGAL	The first officer had what was thought to be indigestion before departure. After the F/O stretched and raised an arm, the airman stated that it felt "heavy" and that a weakness was felt in the arm. The F/O broke out into a cold sweat.
81	1998	47	No	No	Incapacitation	UROLOGICAL	The first officer was having chest and abdominal pains. Hospital diagnosed kidney stones.
82	1998	56	No	No	Incapacitation	CARDIAC	The captain became intensely nauseated during the flight and developed severe anterior chest heaviness, along with aching discomfort without radiation. The captain broke out into a sweat and it appeared the airman was having a heart attack. The captain was treated onboard by two physicians; given four tablets of nitroglycerin that produced decreased chest discomfort but gave him a headache.
83	1998	55	No	No	Impairment	CARBON DIOXIDE POISONING	The aircraft was taxiing to takeoff when all four occupants became short of breath. All occupants donned oxygen masks, and the captain taxied the airplane back to the ramp. The crew were transported to hospital. Diagnosis was physical impairment resulting from an accumulation in the cockpit of carbon dioxide fumes produced by dry ice, a hazardous material, carried in the main cargo compartment.

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)						
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category
84	1998	28	No	No	Impairment	CARBON DIOXIDE POISONING
The aircraft was taxiing to takeoff when all four occupants became short of breath. All occupants donned oxygen masks, and the captain taxied the airplane back to the ramp. The crew were transported to hospital. Diagnosis was physical impairment resulting from an accumulation in the cockpit of carbon dioxide fumes produced by dry ice, a hazardous material, carried in the main cargo compartment.						
85	1998	27	No	No	Impairment	CARBON DIOXIDE POISONING
The aircraft was taxiing to takeoff when all four occupants became short of breath. All occupants donned oxygen masks, and the captain taxied the airplane back to the ramp. The crew were transported to hospital. Diagnosis was physical impairment resulting from an accumulation in the cockpit of carbon dioxide fumes produced by dry ice, a hazardous material, carried in the main cargo compartment						
86	1998	29	No	No	Impairment	GASTROINTESTINAL DEHYDRATION
The captain had been feeling ill all day. On approach he began to vomit, which continued for a few minutes. Local clinic diagnosed gastroenteritis.						
87	1998	31	No	No	Incapacitation	MISCELLANEOUS
The first officer experienced dizziness when getting up to go for aspirin for an earache. LOC was initially reported, although this was not confirmed.						
89	1998	49	Yes	No	Incapacitation	NEUROLOGICAL (SEIZURE)
The aircraft had just landed when the captain apparently had a seizure episode for over a minute and a half. The captain's body became stiff, the back arched, and the captain bit his tongue, and dislocated/fractured the left shoulder, also sustaining a lumbar compression fracture. The captain caused the aircraft to turn right and come to a sudden stop due to the stretched position. The airman regained consciousness shortly thereafter. The first officer removed the captain from the controls and taxied to the gate.						
95	1998	25	No	No	Incapacitation	LOSS OF CONSCIOUSNESS CARDIAC
During flight the F/O lost consciousness for less than one minute. After regaining consciousness, the F/O was able to fully perform some duties and the flight continued to destination.						

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)						
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category
						CAMI Narrative
96	1994	57	No	No	Incapacitation	NEUROLOGICAL (SEIZURE)
						During a transatlantic flight, the captain lost consciousness. The aircraft diverted. The captain was in the jump seat at the time, the episode was described as an out-of-body sensation with the head jerking to the right. The captain passed out and became wedged in between the cockpit seats. The captain was unresponsive with arms folded across the chest. The captain was stiff, and did bite the tongue. However, he regained his senses in less than one minute and did not describe any significant postictal phase.
97	1998	43	No	No	Impairment	RESPIRATORY
						On departure, the F/O experienced increasing pain and pressure in the sinuses and right inner ear. The pain became worse as the aircraft ascended; pressure increased and was accompanied by numbness. Flight diverted, the pain subsided on descent and was tolerable at sea level.
98	1998	34	No	No	Incapacitation	GASTROINTESTINAL
						The flight diverted after the F/O became ill. It was reported the F/O had flu-like symptoms, cramps and vomiting, but did not lose consciousness.
100	1994	59	No	No	Incapacitation	MISCELLANEOUS
						Inflight, the captain's performance was poor and inattentive, with portions of his speech being unrecognizable. The first officer assumed all flight deck duties but the captain wanted to participate and to avoid a confrontation the F/O allowed the captain to assist, but the duties became very difficult for the captain to accomplish. After landing, the captain assisted in parking the aircraft but was unable to respond intelligently.
148	1996	48	Yes	No	Impairment	VISION
						The airplane struck the approach light structure and the end of the runway deck during the approach. Because of the captain's use of monovision contact lenses, the airman was unable to overcome the visual illusions resulting from the approach over water in limited light. These illusions led the captain to perceive that the airplane was higher than it was during the visual portion of the approach, and thus, to his unnecessarily steepening the approach during the final 10 seconds before impact.

Case Summaries Shaded sequential cases occurred on the same flight (i.e. cases 16-17, 83-85, and 218-219)							
Case	Year	Age	Safety of Flight Issue	Deceased	Event	Category	CAMI Narrative
175	1993	33	No	No	Incapacitation	NEUROLOGICAL (SEIZURE)	First officer experienced LOC in-flight, and experienced feeling disorientated, presyncopal and "numb all over" for 10 seconds prior to the LOC. The F/O was witnessed to have a 5-minute episode of tonic-clonic convulsions, with a postictal state accompanied by confusion.
178	1994	52	No	No	Incapacitation	LOSS OF CONSCIOUSNESS DECOMPRESSION SICKNESS	During climbout, the crew was unable to pressurize the airplane. The crew donned oxygen masks and climb was continued to FL330. Shortly after level-off, the captain became incapacitated from decompression sickness. The flight diverted.
218	1993	54	Yes	No	Impairment	FATIGUE	Additional factors contributing to the cause were the inadequacy of the flight and duty time regulations applied to 14 CFR, PART 121, Supplemental Air Carrier, International Operations, and the circumstances that resulted in the extended flight/duty hours and fatigue of the flight crew.
219	1993	50	Yes	No	Impairment	FATIGUE	Additional factors contributing to the cause were the inadequacy of the flight and duty time regulations applied to 14 CFR, PART 121, Supplemental Air Carrier, International Operations, and the circumstances that resulted in the extended flight/duty hours and fatigue of the flight crew.

